

STANDARDIZED AGE-SPECIFIC CATCH RATES IN NUMBER OF FISH FOR THE NORTH ATLANTIC SWORDFISH (*Xiphias gladius*) INFERRED FROM DATA OF THE SPANISH LONGLINE FLEET DURING THE PERIOD 1982-2019

¹Jaime Mejuto, Blanca García-Cortés, Ana Ramos-Cartelle and José Fernández-Costa

SUMMARY

Standardized ages specific 1-5+ catch rates in number of fish were updated for a period of 38 years using log-normal General Linear Model (GLM) from 11,842 trips (145,294 fishing days, 262.8×10^6 hooks) of the Spanish surface longline targeting swordfish in the North Atlantic stock. The models took into consideration factors such as gear-style and a target variable to allow for the two most important changes in fishing strategy in recent periods. The base case models explained between 41%-46% of CPUE variability. The standardized CPUE for age 1 suggests a very positive phase of recruitments between periods 1997-2012 and also 1997-2019 with an overall mean of around double the relative abundance compared to the 1982-1996 mean level. This positive phase had positive effects on other ages including ages 5+ and the subsequent demographic changes since mid-1990s onwards which could be the main cause for explaining different availabilities by size and age and different average weights and overall CPUEs between different regions-fleets.

RÉSUMÉ

Les taux de capture standardisés spécifiques aux âges 1-5+ en nombre de poissons ont été mis à jour pour une période de 38 ans en utilisant un modèle linéaire généralisé (GLM) log-normal à partir de 11.842 sorties (145.294 jours de pêche, $262,8 \times 10^6$ hameçons) des palangriers de surface espagnols ciblant l'espadon dans l'Atlantique Nord. Les modèles ont pris en compte des facteurs tels que le type d'engin et une variable cible pour tenir compte des deux changements les plus importants dans la stratégie de pêche au cours des périodes récentes. Les cas de base du modèle ont expliqué entre 41% et 46% de la variabilité des CPUE. La CPUE standardisée pour l'âge 1 suggère une phase très positive de recrutements entre les périodes 1997-2012 et 1997-2019 avec une moyenne globale d'environ le double de l'abondance relative par rapport au niveau moyen de 1982-1996. Cette phase positive a eu des effets favorables sur les autres âges, y compris les âges 5+. Les changements démographiques ultérieurs depuis le milieu des années 1990 pourraient être la principale cause expliquant les différentes disponibilités par taille et par âge et les différents poids moyens et CPUE globales entre les différentes régions-flottes.

RESUMEN

Se actualizaron para 38 años las tasas de captura normalizadas en número por edad 1-5+ mediante Modelos Lineales Generalizados (GLM) a partir de 11.842 mareas (145.294 días de pesca, $262,8 \times 10^6$ anzuelos) de la flota española de palangre de superficie dirigida al pez espada en el stock Atlántico norte. Los modelos tomaron en consideración factores como el estilo del arte de pesca y una variable objetivo para evaluar los dos cambios más importantes en la estrategia de pesca en períodos recientes. Los modelos "base-case" explicaron entre el 41%-46% de la variabilidad de la CPUE. El índice estandarizado de CPUE edad 1 sugiere una fase muy positiva de reclutamientos entre 1997-2012 y también entre 1997-2019 con un valor medio global de abundancia sobre el doble al del periodo 1982-1996. Esa positiva fase tuvo efectos positivos sobre las otras edades, incluida la del grupo de edades 5+, y un el cambio demográfico subsiguiente ocurrido a partir de mediados de los noventa que podría ser la principal causa para explicar la distinta disponibilidad por talla y edad, el peso medio y de las CPUE globales entre las distintas áreas-flotas.

¹ Instituto Español de Oceanografía. Consejo Superior de Investigaciones Científicas. P.O. Box 130, 15080 A Coruña. Spain.
tunidos.corunha@ieo.es
<http://www.co.ieo.es/tunidos/>

KEYWORDS

Swordfish, age specific CPUE, GLM, longline

1. Introduction

Standardized catch rates of the Atlantic swordfish stocks were obtained from the 1980s onwards by means of *General Linear Models* (GLM) applied to data of different commercial longline fleets, some of which targeted this species while others did not (e.g. Hoey *et al.* 1989, 1993, Anon. 1989, 2010, Nakano 1993, Mejuto 1993, 1994, Scott *et al.* 1993, Mejuto and de la Serna 1995, 1997, 2000, Mejuto *et al.* 1999, Ortiz and Scott 2003). Data collected since the eighties for scientific purposes from the commercial Spanish surface longline fishery targeting swordfish had been also used to develop GLM standardized catch per unit effort for the North Atlantic swordfish stock using methods recommended by several authors and the ICCAT method working groups (e.g. Anon. 1989, 2001, 2010, 2014, Gavaris 1980, Kimura 1981, Robson 1966). Some of these indicators considered as reliable and qualitatively and quantitatively robust, have been selected as indices of relative abundance and implemented as input parameters for some assessments of North Atlantic swordfish stock. Implicit in this approach is the assumption that the catch and effort data used adequately cover at least an important range of both the fishery and the exploited stock (Shibano *et al.* 2021). This assumption may be violated in some fleets if catches modelled are minor, the fishery is frequently changing the target species through changes in the fishing areas-times as well as in the gear configurations and depth in fishing gears, and/or the day-night fishing patterns for targeting different species, etc.; and all these variations are not duly recorded neither considered in GLM runs.

Abundant information on the history and evolution of this longline fishery in this North Atlantic swordfish stock is described in detail in many contributions since 1980s, as well as the reasons why some methodological approaches were selected and implemented based on the field observation on the development of this fishery over decades. Details are not reiterated in the present paper, but their reading and consideration are recommended to avoid revisiting approaches tested and to know the reasons why some decisions were considered by authors and the ICCAT working groups.

In summary, the surface longline gear of the Spanish fleet targeting swordfish remained relatively constant over several decades of twentieth century regarding their fishing practices, structure and gear configuration (Rey *et al.* 1988, Hoey *et al.* 1988, 1989). The consistency of the fishing patterns, fishing areas-times and gear configurations during decades facilitated the interpretation and assumption of those catch rates as indices of relative abundance from regularly broad temperate areas of the Eastern and central North Atlantic taking advantage of the geographical expansion of this fleet during the eighties. These indices have been considered as complementary to those developed for fleets fishing swordfish between warm and temperate waters throughout North-western regions. Some technological improvements in the constant shallow and night setting fishing gear of this fleet were introduced and described during those historical periods, mostly in order to make it easier to carry out handling, related to setting out and hauling back the fishing gear. These old improvements in the traditional surface longline gear generally tended to allow for a greater number of hooks per set which were considered as nominal effort in the respective analyses, task two data and CPUE calculations.

However, changes in the fishing strategy and the gear “style” of the Spanish longline fleet have been introduced and scientifically reported since the end of the last century. The monofilament mainline “*American style*” longline (originally based on the “*Florida style longline*”) was widely introduced in the Spanish Atlantic fleet at the end of the past century, most vessels have been fishing with this style since then and the gear styles were implemented in the GLM runs (e.g. Mejuto and De la Serna 2000, Mejuto *et al.* 2003, García-Cortés *et al.* 2014, 2017). On the other hand, the targeting criteria of the Spanish longline fleet fishing on the North Atlantic stock was historically based on targeting swordfish. But this strategy has later become progressively more diffuse when frozen systems were introduced onboard instead of ice in most boats and quotas of swordfish allocated, focusing on a combination of both swordfish and blue shark as the main abundant, fully retained and valuable species, as was also observed and reported for these or other groups of species (e.g. sharks, tuna and / vs. swordfish) in the case of several North and South Atlantic surface longline fleets described in the abundant scientific literature available. The “target variable” accounts for trips where tunas and/or sharks were important or even predominant in the catch of some described fleets, or potentially also targeted as main species for some other longline Atlantic fleets. These changes in the fishing strategy of a number of fleets in the North and South Atlantic Ocean have been reported and they had significant effects on the standardized CPUE for swordfish obtained from each fleet using different and adapted methods and models to each case (e.g. Carvalho *et al.* 2010,

Hazin *et al.* 2010, Mejuto and De la Serna 2000, Ortiz 2010, Ortiz and Scott 2003, Ortiz *et al.* 2010, Paul and Neilson 2010). The impact of these changes on the nominal and standardized CPUE of the Spanish fleet have been significant as largely described in literature available (see previous references), compared and discussed with results obtained using other approaches such as considering different methods of categorization of the type of trips and the different levels of the factors (e.g. Anon. 2001, Mejuto and De la Serna 1997, 2000; Mejuto *et al.* 1998, 1999, 2001, 2002). These new factors and levels finally selected had already been assessed and considered in the age-aggregated CPUE standardizations. However, the new main events occurring throughout some periods of the recent history of the fishery had not been taken into account in the age-specific CPUE analyses until recent contributions (Mejuto *et al.* 2014, 2017) and the respective stock assessments (Anon. 2014, 2017^{a,b}). New changes have not occurred in the fishing strategy of this fleet since the most recent descriptions presented, except for the implementation and adaptation to the domestic regulations.

The aim of this document is to update the standardized CPUE series (ages 1 to 5+) for the North Atlantic swordfish stocks covering in this case a 38-year period of scientific data. Environmental considerations are omitted in the present paper but a large discussion upon that matter is summarized in several previous contributions (e.g. Mejuto *et al.* 2017).

2. Material and methods

Trip data used were scientifically obtained from landings of the Spanish longline fleet fishing in the North Atlantic swordfish stock over a period of 38 years (1982-2019). Information about the historical record is also available in Hoey *et al.* (1998, 1999) as well as in the subsequent contributions submitted since then. Data voluntarily reported for scientific purposes was recorded and used.

The methods and specifications used in this paper aimed to be consistent as far as possible with previously achieved methodological advances and the analyses focussed in order to facilitate comparison with earlier results. The two most important events which have occurred –see introduction– were also taken into consideration in the present analyses: (a) The introduction of a new monofilament gear style (American style) and (b) the progressive change over time of the targeting criteria of this fleet compared with the historical decades reported. Both main events were described and assessed in previous contributions.

The analysis of standardized CPUE by age approximation (number of fish per thousand hooks) was developed using the methods traditionally applied in the ICCAT swordfish working groups and also implemented in previous papers (e.g. Mejuto 1993, 1994, Mejuto and De la Serna 1995, 1997, 2000; Mejuto *et al.* 1998, 1999, 2003, 2014, 2017). The updated sex-combined Gompertz's type growth model (Restrepo 1990) recommended and assumed by ICCAT based on tagging-recapture data (Anon. 1989) was used to obtain the number of fish by age (ages 1 to 5+) from catch size data sampled per trip. The conversion from size into "age" was carried out using the ICCAT software "aging" implemented in the north Atlantic swordfish case but also in other ICCAT species-stock assessments to convert CAS to CAA applying the "slicing" technique from their respective growth models. This software was originally written in FORTRAN but later updated to a QBasic language (Restrepo *pers. comm.*) for a more user-friendly management and the open implementation to all swordfish ICCAT scientists.

Trips with size-sampling coverage below 85% of the total catch in number of fish landed were omitted from the base case GLM analysis as decided in previous contributions to avoid or reduce possible bias in the sampling of some size-ranges per trip. However, a sensitivity analysis was also performed considering a lower and less demanding size sampling coverage of 50% for the selection of trip records used for the GLM sensitivity runs. Other levels of coverage had been already assessed in previous contributions.

The *type of trip* or the fishing strategy for the targeting (the target variable), the gear style and the bait used were also considered for modelling. The *type of trip* was categorized as the percentage (ratio) in weight of swordfish landed by trip in relation to the amount of combined swordfish and blue shark landed. This information indicates the prioritization followed by the skippers during the trips in relation to both species (SWO or SWO+BSH). After analyzing the behaviour of this fleet over time, testing several methodological approaches of categorization of the trips (including clusters and other) and assessing the impact of this variable within the nominal CPUE and models, it was concluded that this ratio is the best proxy indicator for the skippers targeting criteria belonging to this fleet over time to categorize the type of trip and their comparison with the initial time periods of this series (Mejuto and De la Serna 2000, Ortiz *et al.* 2010), and performed best among the different proxies simulated (Anon. 2001). Taking into consideration previous analyses and conclusions achieved, the "ratio" was broken

down into ten categories at 10% intervals for modelling the levels of type of trip. Complementary information about the period of progressive transition 1986-2000 for the change in targeting in this fleet and the effects on the nominal and standardized CPUE of each level of ratio can be found in previous contributions (e.g. Mejuto and De la Serna 2000, Mejuto 2007).

The definition corresponding to "quarters" was as follows: Q1 = January, February, March; Q2 = April, May, June; Q3 = July, August, September; Q4 = October, November and December. Three gear styles were defined: 1 = traditional multifilament mainline, 3 = new monofilament and 9 = unknown. Three bait types were also considered: 1 = mackerel, 6 = squid and 9 = other types or combinations.

The hypothetical boundary line between North and South Atlantic stocks was kept at 5°N latitude as assumed by the ICCAT based on conventional tag-recapture data and other evidences (Anon. 2014, 2017^{a,b}, García-Cortés *et al.* 2003) as well as largely supported by the electronic tagging (pop-up) studies carried out (e.g. Abascal *et al.* 2015, Braun *et al.* 2019, Neilson *et al.* 2009, 2013, 2014). The spatial definition used for final runs also considered five areas as in previous analyses by age (Mejuto *et al.* 2014, 2017) and was also considered in overall number of fish and biomass GLM analyses for this fleet (García-Cortés *et al.* 2014, 2017; Ramos-Cartelle *et al.* 2021-in press).

The base case standardized log-normal CPUE analyses were performed using GLM procedures (SAS 9.4 ver.). The models were defined as: $\text{Ln}(\text{CPUE}) = \mu + Y + Q + A + G + B + R + Q \cdot A + e$. Where: μ = overall mean, Y = year effect, Q = time effect (quarter), A = area effect, G = gear style effect, B = bait type, R = "ratio" effect, e = logarithm of the normally distributed error term. More details about the methods and criteria implemented as well as discussions can be found in the papers previously cited.

Old trip records from the period 1982-1985 lacked some of the information for this modelling approach, as regards details such as the gear style and bait type used, as well as regarding the "ratio" information between the two species. In such cases, taking into consideration the history of this fishery, the available literature and knowledge, the traditional gear style and mackerel for bait were assumed for all trips during that initial period. A ratio equal to the average observed for trips in 1986 was retrospectively applied to all trips in the old period 1982-1985.

3. Results and discussion

A total number of 11,842 trip-observations (262.849 million hooks, 145,294 fishing days) from the whole period 1982-2019 fulfilled the demanding size-coverage and other criteria established for a base case analyses. **Table 1** is a summary of the ANOVA results for each age-specific analysis. The number of observations used, R-square, mean square error (root) and F-statistics for each age class are provided. The base case models by age explained between 41% and 46% of CPUE variability.

Table 2 shows the estimated parameters obtained from the CPUE analyses in number of fish by age for the base case runs. The quarter, area and gear are the most important factors for explaining variability of the age 1 CPUE. The year variable seems to be also relatively important for age 1 suggesting that inter-annual variability plays a relatively important or moderate role. Area, gear and ratio are the main factors for age 2. But gear and ratio are regularly the most important factors in ranking for main ages targeted, along with the area or quarter factors. The type III SS suggest a different ranking of factors for the different ages, as would be expected in a species segregated to some extent according to the size-age with some of these ages being mainly targeted by this fleet with extensive fishing experience over time. The bait factor regularly explained a minor or negligible part of CPUE variability or was not significant for one age.

Figures 1 and 2 represent the normal fit, the frequency distribution of the standardized residuals and the normal probability *qq-plot* diagnosis of the GLM base case runs for standardized CPUE in number of swordfish by age. **Figure 3** presents the variability box-plot of the standardized residuals by year for each age.

Table 3(a-e) provides information on estimated parameters, their standard error, standardized CPUE by age and upper and lower 95% confidence limits obtained for the base case runs. CVs are omitted given that they lose meaning when the mean values are close to zero, giving very large CVs that do not necessarily imply scatter of data in those cases. The mean standardized CPUE figures by age and their 95% confidence intervals are plotted (**Figure 4**). The results for age 1 suggest that the mean relative abundance of this age during the whole periods 1997-2012 or 1997-2019 were around 2.2 and 2.0 times greater respectively, than the mean level predicted for

the period 1982-1996. The results obtained for the whole ages 1-5+ from the size samples are generally very consistent with those obtained in the analysis of standardized CPUE in total number of fish per trip (Ramos-Cartelle *et al.* 2021-in press) (**Figure 5**).

The sensitivity analysis including trips with at least a 50% size-sampling coverage of the catch in number did not produce important effects on most general CPUE trends over time for the whole period analyzed. The trends obtained versus the base case run were similar although with a lower fit, broader confidence intervals for all ages and other less satisfactory statistical indicators. The results confirm previous ones by testing different thresholds in the coverage of the size-sampling data per trip, suggesting that in the case of the size-age specific CPUE analysis the size-sampling criteria and protocols used for each fleet to obtain the full CAS data per observation could be an important factor in considering such results as reliable and for comparing them with results provided from other fleets. In the present and previous contributions no substitution procedure of size information among trips was implemented and a very demanding criterion of minimum size-sampling coverage per trip was selected for the base case runs to avoid potential bias. The CPUEs by age from several fleets had also been provided for previous North Atlantic swordfish assessments. The use of models structured by age and the informative importance of these indices made it advisable to provide this type of information but as well as providing details about the CAS data used and methodology in each observation modelled. High levels of coverage per trip are regularly recommended and substitutions of size data among trips-observations should be avoided.

The authors and previous ICCAT SWO working groups have been aware of the drawbacks of using slicing methods or other alternative methods also tested in the past and applying the growth model selected in the assessments to convert length into “age” when there are no age-length keys available nor other better and successful ageing proposals achieved and validated. Tagging-recapture data (sex-combined) was considered so far the most accurate growth approach. Despite the huge difficulty of obtaining highly representative CAS data by trip over almost four decades and obtaining the CAA using the sex-combined growth model from tagging-recapture data -as recommended and assumed by ICCAT for North Atlantic swordfish (Anon. 1989)- these CPUE indicators by “age” or “proxies” could also help to better understand stock dynamics and interpret those trends observed in the CPUE of each fleet, and between fleets, when standardized catch rates (in terms of aggregated number or in biomass) are developed for “ages-combined”.

The CPUE indices by “age” could be especially useful for the interpretation of the standardized age-combined CPUE in biomass due to the high impact of the mean weight of the catch on these combined biomass indices. They could be also useful for the interpretation of the standardized age-combined CPUE in number of fish due to the high impact of some abundant young ages in the catch on some fleets-areas in warmer waters where the “juvenile” fraction can be very important and especially in some areas and periods. However, in the case of age-combined indices and because of the behaviour of the swordfish, it is not easy to discern which fractions of the stock contribute to a greater or lesser extent, in a given year, period or fleet, to that respective age-combined indicator, or those sizes-ages omitted in some calculations provided. It is, therefore, difficult and risky to make comparisons between fleets or periods of their respective combined CPUE trends without knowing the respective fractions and their levels that contributed over time to the different fleets’ annual indices, or those “sizes-ages” omitted in the CPUE calculations in some cases because of lack of availability of data, domestic regulations and mandatory systems used, or other reasons. In short, this type of “age” analyses, despite their limitations and difficulties, may be useful in some cases at least as complementary information to be considered as long as the CAS data are qualitatively adequate and are not affected by size-substitution among observations used in the analyses or affected by insufficient information surrounding size data available or bias.

A study (Shibano *et al.* 2021) proposes the implementation of *Finite Mixture Modeling* (FMM) in the CPUE standardization in those multispecies-fisheries in which the target species is unknown and some of the variables considered in the model do not adequately capture the type of “target”. In those cases, the authors propose that the implementation of FMM models would allow simultaneously estimate the various target species and the annual trends in abundance, compared to methodological alternatives such as suggested by other authors that incorporate the so-called target strategy in the model as an explanatory variable (e.g. Carvalho *et al.* 2010). In the present case, based on the knowledge of the history of this fishery and previous studies since the eighties, the authors also propose to incorporate the stratification of targeting (*type of trip*) within the model as an explanatory variable because it was identifiable and recorded over the years and to be the best approximation in this case. The progressive transition in this case from a strictly SWO targeting to a SWO+BSH fishing strategy occurred during the 1986-2000 period was scientifically tracked, consolidated and manifested itself over the series in the prioritization of the total catch retained between both species within each trip landed. This process was scientifically observed over time and assessed. Likewise, the use of the different levels of the targeting variable has been previously studied and it was considered the most appropriate approach based on previous analyses.

Moreover, this approach is also supported on the fact that there have been no substantial changes in the fishing areas of this fleet throughout the years analyzed, the transition of the longline style occurred was scientifically tracked during the period around the end of the last century and it was also modelled. Nor in this case was there a process of change in terms of the depth of the fishing gear or of the day-night fishing pattern as it had happened in other fleets whose effects are very relevant on the catchability of the different species potentially targeted but whose data are rarely recorded in mandatory log-books. In summary, all changes that have occurred in the fishery analyzed in the present paper have been studied and documented since the 1980s. This approach makes it possible to compare the standardized series during the different periods of activity of this fleet within which these processes have been scientifically followed, whose effects have been specifically evaluated in previous studies and incorporated in standardization analyses. Without ruling out other possible methodological approaches that could be applied to the particular casuistry of other fleets, the suitability of the methods could be compared using numerical simulations adapted to each case. That was in fact the exercise already performed by Anon. (2001) simulating this particular bi-specific scenario and testing several approaches. For these reasons, the methodological approach applied in the case of this fishery is plausible considering its history, the available information and the conclusions about tested scenarios; although this methodological approach does not necessarily performs best for the fishing histories of other fleets throughout the years and considering their respective data availability and diffuse fishing-targeting strategies over time.

It has been in some cases postulated that the introduction of the “targeting” as an explanatory variable within the GLM models could cause a false vision of *hyper-stability* in the standardized CPUE trends. But the truth is that, in the specific case of this fleet and its history over time, it has been seen that the non-inclusion of the progressive change in targeting produces a fake systematic inter-annual *hyper-instability* predicting false changes in the relative abundance throughout the years. The omission of the targeting factor in this specific case would falsely adjudicate a large part of the inter-annual variability in CPUE observed to the year effect (see previous references). But it has been demonstrated in previous studies that a large parte of the inter-annual CPUE variability observed in this fleet was really due to the change in targeting that occurred over a period, with subsequent effects on the respective nominal CPUE of SWO.

The updated figures included in the present study could be considered indicators of the relative abundance of the most prevalent “ages” or “proxies” in this fishery during the period analysed. However, the strict coverage requirements established for the present analysis and the changes in landing procedures and other limitations have considerably reduced the number of observations available after 2011. Moreover, the current management system implemented at domestic level for swordfish is based on a complex and demanding network-based regulatory, *inter alia*, on closed lists of authorized vessels, gear regulations, fishing plans per year-company-boat and the assignment of strict annual quota per vessel. The quota system per boat-year makes vessels extend their fishing activity in an economically sustainable way all year round, while moderating in many cases their levels of swordfish catches per trip and their respective catch rates. The effect of this self-controlled fishing strategy on the standardized CPUE indicators of swordfish is not easily modelled, but it is likely to be causing an underestimate in the abundance index in relation to the fishing strategy of previous historical periods in which global annual quotas were implemented, the highest catch rates were looked for and different control measures were implemented at domestic level. The present authors accordingly place more reliance on indicators of abundance by age prior to 2012.

On the other hand, the first ICCAT recommendation on minimum size came into force formally in July 1991 and was fully implemented in 1992. Since then, these recommendations (with different updates and formulations such as REC-90-2 or REC 95-10) have been maintained by ICCAT with different effects on the respective fleets depending on the options chosen for each CPC and the respective effects on the mandatory or scientific data used. As a consequence, different impacts on the data by fleet should be expected. In the case of this fleet analyzed, the type of REC-90-02 which allowed tolerance of up to 15% of the catch in number had been regularly implemented. However, this tolerance was unilaterally cancelled by the EU at a domestic level between June 2007 and January 2009, but the confusion generated and its effect has been carried over to the present. Therefore, values of CPUE age 1 should be considered with caution since year 2010 but especially for the most recent periods and after 2015 in particular since they were probably underestimated. The authors of the present paper recommend rejecting, at the very least, those values of age 1 since year 2015. In any case, regardless of the representativeness of the probably underestimated values of age 1 for the most recent periods of this series, the results suggest that the overall mean level of annual recruitments would have been proximately around double or more since year 1996 in relation to the mean levels during the period 1981-1995. This positive phase had positive effects on other ages and the subsequent demographic change since mid-1990s onwards, which could be the main cause for explaining different availabilities by size-age, average weights and the overall CPUEs of the different areas-fleets. Environmental considerations related to these indices and environmental phases can be found in several previous contributions (e.g. Mejuto *et al.* 2017).

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References

- Abascal, F.J., Mejuto, J., Quintáns, M., García-Cortés, B. and Ramos-Cartelle, A. 2015. Tracking of the broadbill swordfish, *Xiphias gladius*, in the central and eastern North Atlantic. *Fisheries Research* 162: 20–28.
- Anonymous. 1989. Second ICCAT Swordfish Workshop. Collect. Vol. Sci. Pap. ICCAT, 29: 71-162.
- Anonymous. 2001. Report of the ICCAT working group on stock assessment methods (Madrid, Spain –May 8 to 11, 2000). Collect. Vol. Sci. Pap. ICCAT, 52(5):1569-1662.
- Anonymous. 2010. Report of the 2009 Atlantic swordfish stock assessment session (Madrid, September 7 to 11, 2009). Collect. Vol. Sci. Pap. ICCAT, 65(1): 1-123.
- Anonymous. 2014. Report of the 2013 Atlantic Swordfish Stock Assessment Session (Olhão, Portugal, September 2-10, 2013). Collect. Vol. Sci. Pap. ICCAT, 70(4):1484-1678.
- Anonymous. 2017^a. Report of the 2017 ICCAT swordfish data preparatory meeting (Madrid, Spain 3-7 April, 2017). Collect. Vol. Sci. Pap. ICCAT, 74(3): 729-840.
- Anonymous. 2017^b. Report of the 2017 ICCAT Atlantic swordfish stock assessment session (Madrid, 3-7 July, 2017). Collect. Vol. Sci. Pap. ICCAT, 74: 841-967.
- Braun, C.D., Gaube, P., Afonso, P., Fontes, J., Skomal, G.B. and Thorrold, S.R. 2019. Assimilating electronic tagging, oceanographic modelling, and fisheries data to estimate movements and connectivity of swordfish in the North Atlantic. *ICES Journal of Marine Science*, 76: 2305–2317.
- Carvalho, F.C., Murie, D.J., Hazin, F.H.V., Hazin, H.G., Leite-mourato, B., Travassos, P., Burgess, G.H. 2010. Catch rates and size composition of blue sharks (*Prionace glauca*) caught by the Brazilian pelagic longline fleet in the southwestern Atlantic Ocean. *Aquat. Liv. Resour.*, 23:373–385.
- García-Cortés, B., Mejuto, J. and Quintáns, M. 2003. Summary of swordfish (*Xiphias gladius*) recaptures carried out by the Spanish surface longline fleet in the Atlantic Ocean: 1984-2002. Collect. Vol. Sci. Pap. ICCAT, 55(4): 1476-1484.
- García-Cortés, B., Ramos-Cartelle, A., Fernández-Costa, J. and Mejuto, J. 2017. Standardized catch rates for the North Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish surface longline fleet for the period 1986-2015. Collect. Vol. Sci. Pap. ICCAT, 74(3): 1182-1196.
- García-Cortés, B., Ramos-Cartelle, A. and Mejuto, J. 2014. Standardized catch rates in biomass for North Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish surface longline fleet for the period 1986-2011. Collect. Vol. Sci. Pap. ICCAT, 70(4): 1792-1803.
- Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. *Can. J. Fish. Aquat. Sci.* 37: 2272-2275.
- Hazin, H.G., Mente-Vera, C.V., Hazin, F., Travassos, P., Carvalho, F. and Mourato, B. 2010. Standardized CPUE series of swordfish, *Xiphias gladius*, caught by Brazilian tuna fisheries in the southwestern Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 65(1): 274-284.

- Hoey, J., Mejuto, J. and Conser, R. 1989. CPUE indices derived from combined Spanish and U.S. catch and effort data. Collect. Vol. Sci. Pap. ICCAT, 29: 228-249.
- Hoey, J., Mejuto, J., Iglesias, S. and Conser, R. 1988. A comparative study of the United States and Spanish longline fleet targeting swordfish in the Atlantic Ocean, North of 40° latitude. Collect. Vol. Sci. Pap. ICCAT, 27: 230-239.
- Hoey, J.J., Mejuto, J., Porter, J. and Uozumi, Y. 1993. A standardized biomass index of abundance for North Atlantic swordfish. Collect. Vol. Sci. Pap. ICCAT, 40(1): 344-352.
- Kimura, D.K. 1981. Standardized measures of relative abundance based on modeling log (CPUE) and their application to Pacific Ocean Perch. J. Cons. Int. Explor. Mer. 39: 211-218.
- Mejuto, J. 1993. Age specific standardized indices of abundance for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-1991. Collect. Vol. Sci. Pap. ICCAT, 40(1): 371-392.
- Mejuto, J. 1994. Standardized indices of abundance at age for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-1992. Collect. Vol. Sci. Pap. ICCAT, 42(1): 328- 334.
- Mejuto, J. 2007. Aspectos biológicos y pesqueros del pez espada (*Xiphias gladius*, Linnaeus, 1758) del océano Atlántico, con especial referencia a las áreas de actividad de la flota española. Tesis doctoral. 265pp.
- Mejuto, J. and De la Serna, J.M. 1995. Standardized catch rates by age and length groups for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-93. Collect. Vol. Sci. Pap. ICCAT, 19(3): 114-125.
- Mejuto, J. and De la Serna, J.M. 1997. Updated standardized catch rates by age for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, using commercial trips from the period 1983-1995. Collect. Vol. Sci. Pap. ICCAT, 46(3): 323-335.
- Mejuto, J. and De la Serna, J.M. 2000. Standardized catch rates by age and biomass for the North Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1998 and bias produced by changes in the fishing strategy. Collect. Vol. Sci. Pap. ICCAT, 51(5): 1387-1410.
- Mejuto, J., De la Serna, J.M. and García, B. 1998. Updated standardized catch rates by age, sexes combined, for the swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, for the period 1983-1996. Collect. Vol. Sci. Pap. ICCAT, 48(1): 216-222.
- Mejuto, J., De la Serna, J.M. and García, B. 1999. Updated standardized catch rates by age, combined sexes, for the swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, for the period 1983-1997. Collect. Vol. Sci. Pap. ICCAT, 49(1): 439-448.
- Mejuto, J., García, B. and De la Serna, J.M. 2001. Standardized catch rates for the North and South Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1999. Collect. Vol. Sci. Pap. ICCAT, 52(4): 1264-1274.
- Mejuto, J., García-Cortés, B. and De la Serna, J.M. 2002. A note on preliminary standardized catch rates for the North Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983- 2000. Collect. Vol. Sci. Pap. ICCAT, 54(5): 1550-1554.
- Mejuto, J., García-Cortés B. and De la Serna, J.M. 2003. Standardized catch rates for the North and South Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-2001. Collect. Vol. Sci. Pap. ICCAT, 55(4): 1495-1505.
- Mejuto, J., García-Cortés, B. and Ramos-Cartelle, A. 2014. Standardized catch rates in number of fish by age for the North Atlantic swordfish (*Xiphias gladius*) of the Spanish longline fleet, for the period 1983-2011. Collect. Vol. Sci. Pap. ICCAT, 70(4): 1912-1825.

- Mejuto, J., García-Cortés, B., Ramos-Cartelle, A. and Fernández-Costa, J. 2017. Standardized catch rates in number of fish by age for the north Atlantic swordfish (*Xiphias gladius*) inferred from the Spanish longline fleet for the period 1982-2015 and environmental considerations. Collect. Vol. Sci. Pap. ICCAT, 74(3): 1208-1234.
- Nakano, H. 1993. Estimation of standardized CPUE for the Atlantic swordfish using the data from the Japanese longline fishery. Collect. Vol. Sci. Pap. ICCAT, 40(1): 357-370.
- Neilson, J., Arocha, F., Cass-Calay, S., Mejuto, J., Ortiz, M., Scott, G., Smith, C., Travassos, P., Tserpes, G. and Andrushchenko, I. 2013. The Recovery of Atlantic Swordfish: The Comparative Roles of the Regional Fisheries Management Organization and Species Biology. Reviews in Fisheries Science, 21(2): 59-97.
- Neilson, J.D., Loefer, J., Prince, E.D., Royer F. and Calmettes, B. 2014. Seasonal distribution and migrations of Northwest Atlantic swordfish: influence from integration of pop-up satellite archival tagging studies. PLoS One 9(11). E112736.
- Neilson, J.D., Smith, S., Royer, F., Paul, S.D., Porter, J.M. and Lutcavage, M. 2009. Investigations of horizontal movements of Atlantic swordfish using pop-up satellite archival tags. [In]: Nielsen, J.L., Arrizabalaga, H., Fragoso, N., Hobday, A., Lutcavage, M., Sibert, J. (Eds.), Tagging and Tracking of Marine Animals with Electronic Devices, Reviews: Methods and Technologies in Fish Biology and Fisheries, 9. Springer, New York, pp. 145–159 (452 pp).
- Ortiz, M. 2010. Update of standardized catch rates by sex and age for swordfish (*Xiphias gladius*) from the U.S. longline fleet 1981-2008. Collect. Vol. Sci. Pap. ICCAT, 65(1): 147-170.
- Ortiz, M. and Scott, G.P. 2003. Standardized catch rates by sex and age for swordfish (*Xiphias gladius*) from the U.S. longline fleet 1981-2001. Collect. Vol. Sci. Pap. ICCAT, 55(4): 1536-1561.
- Ortiz, M., Mejuto, J., Paul, S., Yokawa, K., Neves, M. and Idrissi, M. 2010. An updated biomass index of abundance for North Atlantic swordfish (*Xiphias gladius*) for the period 1963-2008. Collect. Vol. Sci. Pap. ICCAT, 65(1): 171-184.
- Paul, S.D. and Neilson, J.D. 2010. An exploration of targeting variables in the Canadian swordfish longline CPUE. Collect. Vol. Sci. Pap. ICCAT, 65(1): 124-134.
- Ramos-Cartelle, A., Fernández-Costa, J., García-Cortés, B. and Mejuto, J. (2021-in press). Updated standardized catch rates for the north Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish surface longline fleet for the period 1986-2019. Collect. Vol. Sci. Pap. ICCAT, Vol. xx (x): xxxx-xxxx.
- Restrepo, V. 1990. An update of the swordfish tagging data for use in growth analyses. Collect. Vol. Sci. Pap. ICCAT, 32(2):360-370.
- Rey, J.C., Mejuto, J. and Iglesias, S. 1988. Evolución histórica y situación actual de la pesquería de pez espada (*Xiphias gladius*). Collect. Vol. Sci. Pap. ICCAT, 27: 202-213.
- Robson, D. S., 1966. Estimation of relative fishing power of individual ships. Res. Bull. Int. Comm. N.W. Atl. Fish, 3: 5-14.
- Scott, G.P., Restrepo, V.R. and Bertolino, A. 1993. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet though 1991. Collect. Vol. Sci. Pap. ICCAT, 40(1): 458-468.
- Shibano, A., Kanaiwa, M. and Kai, M. 2021. Performance of a finite mixture model in CPUE standardization for a longline fishery with target change. Fisheries Science, <https://doi.org/10.1007/s12562-021-01515-8>: 13pp.

Table 1. Summary of ANOVA base case analysis in number of fish by age: Number of trip-observations finally used, R- square fit, mean square error (root), F-statistics and Pr > F, for each age group considered.

Age	# Observa.	R-Square	RMSE	F-Stat	Pr > F
1	10597	0.4393	0.9680	119.55	<0.0001
2	11539	0.4618	0.7217	142.63	<0.0001
3	11499	0.4348	0.6660	127.41	<0.0001
4	11186	0.4106	0.6825	112.25	<0.0001
5+	10961	0.4459	0.7264	127.01	<0.0001

Table 2. Summary of ANOVA by factor for CPUE base case analysis, in number of fish by age-group in the North Atlantic stock for the 1982-2019 period.

Age	Factor	DF	Type III SS	Mean-Square	F-value	Pr > F
1	Year	37	1259.117375	34.030199	36.32	<.0001
1	Quarter	3	986.209352	328.736451	350.81	<.0001
1	Area	4	607.116355	151.779089	161.97	<.0001
1	Gear	2	107.876255	53.938128	57.56	<.0001
1	Bait	2	27.824130	13.912065	14.85	<.0001
1	Ratio	9	361.500801	40.166756	42.86	<.0001
1	Quarter*Area	12	221.910253	18.492521	19.73	<.0001
2	Year	37	688.972615	18.620881	35.75	<.0001
2	Quarter	3	151.084005	50.361335	96.68	<.0001
2	Area	4	488.848707	122.212177	234.62	<.0001
2	Gear	2	210.776385	105.388192	202.32	<.0001
2	Bait	2	10.840632	5.420316	10.41	<.0001
2	Ratio	9	1064.140073	118.237786	226.99	<.0001
2	Quarter*Area	12	149.776307	12.481359	23.96	<.0001
3	Year	37	422.501188	11.418951	25.75	<.0001
3	Quarter	3	13.833120	4.611040	10.4	<.0001
3	Area	4	201.228983	50.307246	113.43	<.0001
3	Gear	2	261.002668	130.501334	294.23	<.0001
3	Bait	2	11.912971	5.956485	13.43	<.0001
3	Ratio	9	1203.956110	133.772901	301.61	<.0001
3	Quarter*Area	12	72.520189	6.043349	13.63	<.0001
4	Year	37	467.314403	12.630119	26.65	<.0001
4	Quarter	3	105.487102	35.162367	74.18	<.0001
4	Area	4	94.764588	23.691147	49.98	<.0001
4	Gear	2	246.905053	123.452527	260.45	<.0001
4	Bait	2	8.037594	4.018797	8.48	0.0002
4	Ratio	9	1288.866058	143.207340	302.12	<.0001
4	Quarter*Area	12	34.238665	2.853222	6.02	<.0001
5+	Year	37	671.713795	18.154427	34.4	<.0001
5+	Quarter	3	301.889780	100.629927	190.7	<.0001
5+	Area	4	323.141263	80.785316	153.09	<.0001
5+	Gear	2	151.254018	75.627009	143.31	<.0001
5+	Bait	2	7.293148	3.646574	6.91	0.001
5+	Ratio	9	1120.466241	124.496249	235.92	<.0001
5+	Quarter*Area	12	93.447678	7.787307	14.76	<.0001

Table 3(a). Estimated parameters (Lsmean), standard error (Stderr), standardized CPUE in number by **age 1** (Cpue1) and upper and lower 95% confidence limits (Ucpue1, Lcpue1) for the case base analysis of the North Atlantic for the years 1982-2019.

YR	LSMEAN	STDERR	Ucpue1	Cpue1	Lcpue1
1982	-1.65173	0.31521	0.374	0.201	0.109
1983	-1.19513	0.24963	0.509	0.312	0.191
1984	-1.21384	0.24963	0.500	0.306	0.188
1985	-1.22793	0.24353	0.486	0.302	0.187
1986	-0.85215	0.23685	0.698	0.439	0.276
1987	-0.41995	0.24198	1.087	0.677	0.421
1988	-0.20888	0.23439	1.320	0.834	0.527
1989	-0.39435	0.23498	1.098	0.693	0.437
1990	-0.96796	0.23528	0.619	0.391	0.246
1991	-1.07849	0.23455	0.554	0.350	0.221
1992	-0.99126	0.23403	0.603	0.381	0.241
1993	-0.78872	0.23409	0.739	0.467	0.295
1994	-0.78337	0.23342	0.742	0.469	0.297
1995	-0.73952	0.23216	0.773	0.490	0.311
1996	-0.73619	0.23223	0.776	0.492	0.312
1997	-0.00493	0.23327	1.615	1.023	0.647
1998	-0.13297	0.23328	1.421	0.900	0.570
1999	0.03742	0.23553	1.694	1.067	0.673
2000	0.04301	0.23690	1.708	1.074	0.675
2001	0.11741	0.23558	1.835	1.156	0.729
2002	-0.20407	0.23543	1.330	0.838	0.528
2003	-0.21047	0.23707	1.326	0.833	0.524
2004	-0.23727	0.23910	1.297	0.812	0.508
2005	-0.24189	0.24047	1.295	0.808	0.504
2006	0.17139	0.24226	1.965	1.222	0.760
2007	0.37425	0.24849	2.440	1.499	0.921
2008	0.26899	0.24921	2.200	1.350	0.828
2009	-0.52697	0.25212	0.999	0.609	0.372
2010	-0.33437	0.24531	1.193	0.738	0.456
2011	0.15068	0.24607	1.941	1.198	0.740
2012	-0.19398	0.25035	1.388	0.850	0.520
2013	-0.43529	0.25500	1.102	0.668	0.406
2014	-0.49437	0.25595	1.041	0.630	0.382
2015	-0.17123	0.25191	1.425	0.870	0.531
2016	-0.48524	0.25433	1.047	0.636	0.386
2017	-0.54043	0.25900	1.001	0.602	0.363
2018	-0.51628	0.26885	1.048	0.619	0.365
2019	-0.76852	0.27815	0.831	0.482	0.279

Note: See text for details about this index (age 1) for recent years.

Table 3(b). Estimated parameters (Lsmean), standard error (Stderr), standardized CPUE in number by **age 2** (Cpue2) and upper and lower 95% confidence limits (Ucpue2, Lcpue2) for the case base analysis of the North Atlantic for the years 1982-2019.

YR	LSMEAN	STDERR	Ucpue2	Cpue2	Lcpue2
1982	-0.18738	0.23010	1.337	0.851	0.542
1983	-0.33393	0.18307	1.043	0.728	0.509
1984	-0.53569	0.18193	0.850	0.595	0.417
1985	-0.18083	0.17944	1.206	0.848	0.597
1986	0.05644	0.17565	1.516	1.075	0.762
1987	0.44789	0.17978	2.262	1.591	1.118
1988	0.27677	0.17456	1.885	1.339	0.951
1989	0.42294	0.17485	2.184	1.550	1.100
1990	0.53031	0.17487	2.431	1.726	1.225
1991	0.22382	0.17444	1.788	1.270	0.902
1992	0.19870	0.17414	1.742	1.238	0.880
1993	0.20351	0.17417	1.751	1.244	0.885
1994	0.28494	0.17371	1.897	1.350	0.960
1995	0.53151	0.17277	2.423	1.727	1.231
1996	0.08798	0.17287	1.555	1.108	0.790
1997	0.24851	0.17366	1.829	1.302	0.926
1998	0.58527	0.17362	2.562	1.823	1.297
1999	0.74157	0.17517	3.005	2.132	1.512
2000	0.91545	0.17571	3.580	2.537	1.798
2001	0.87295	0.17517	3.427	2.431	1.725
2002	0.61636	0.17505	2.651	1.881	1.335
2003	0.69846	0.17649	2.886	2.042	1.445
2004	0.35625	0.17735	2.054	1.451	1.025
2005	0.40125	0.17843	2.153	1.518	1.070
2006	0.44957	0.18009	2.268	1.593	1.119
2007	0.74920	0.18444	3.089	2.152	1.499
2008	1.11837	0.18492	4.472	3.113	2.166
2009	0.84135	0.18660	3.402	2.360	1.637
2010	0.84439	0.18173	3.377	2.365	1.657
2011	0.48001	0.18187	2.347	1.643	1.150
2012	0.86523	0.18407	3.466	2.416	1.684
2013	0.53872	0.18803	2.522	1.744	1.207
2014	0.64004	0.18628	2.780	1.930	1.339
2015	0.94603	0.18510	3.766	2.620	1.823
2016	0.24803	0.18662	1.880	1.304	0.905
2017	0.28214	0.18925	1.956	1.350	0.932
2018	0.56049	0.19493	2.616	1.785	1.218
2019	1.03870	0.19743	4.243	2.881	1.957

Table 3(c). Estimated parameters (Lsmean), standard error (Stderr), standardized CPUE in number by **age 3** (Cpue3) and upper and lower 95% confidence limits (Ucpue3, Lcpue3) for the case base analysis of the North Atlantic for the years 1982-2019.

YR	LSMEAN	STDERR	Ucpue3	Cpue3	Lcpue3
1982	-0.26487	0.20868	1.180	0.784	0.521
1983	-0.20279	0.16869	1.153	0.828	0.595
1984	-0.20999	0.16725	1.141	0.822	0.592
1985	-0.12127	0.16526	1.241	0.898	0.650
1986	-0.02041	0.16202	1.364	0.993	0.723
1987	0.20791	0.16589	1.728	1.248	0.902
1988	0.05557	0.16107	1.468	1.071	0.781
1989	-0.05719	0.16138	1.313	0.957	0.697
1990	0.22795	0.16135	1.746	1.272	0.927
1991	0.27259	0.16090	1.824	1.330	0.971
1992	0.18210	0.16067	1.665	1.215	0.887
1993	0.03917	0.16076	1.444	1.053	0.769
1994	-0.11212	0.16028	1.240	0.906	0.661
1995	0.20717	0.15942	1.703	1.246	0.912
1996	-0.09980	0.15952	1.253	0.917	0.671
1997	-0.30497	0.16030	1.022	0.747	0.545
1998	-0.25991	0.16031	1.069	0.781	0.570
1999	0.10951	0.16165	1.552	1.130	0.823
2000	0.34811	0.16215	1.972	1.435	1.044
2001	0.27352	0.16165	1.828	1.332	0.970
2002	0.16239	0.16152	1.636	1.192	0.868
2003	0.27956	0.16287	1.844	1.340	0.974
2004	-0.15583	0.16369	1.195	0.867	0.629
2005	-0.16948	0.16463	1.181	0.856	0.620
2006	-0.27784	0.16643	1.064	0.768	0.554
2007	-0.18229	0.17027	1.181	0.846	0.606
2008	0.14862	0.17093	1.646	1.177	0.842
2009	0.23394	0.17220	1.797	1.282	0.915
2010	0.10240	0.16779	1.561	1.124	0.809
2011	-0.03705	0.16798	1.358	0.977	0.703
2012	0.03429	0.17036	1.466	1.050	0.752
2013	-0.09063	0.17382	1.304	0.927	0.660
2014	0.13528	0.17164	1.627	1.162	0.830
2015	0.35875	0.17108	2.031	1.453	1.039
2016	-0.09452	0.17221	1.294	0.923	0.659
2017	-0.27801	0.17483	1.083	0.769	0.546
2018	-0.15383	0.18049	1.241	0.872	0.612
2019	0.25751	0.18299	1.883	1.316	0.919

Table 3(d). Estimated parameters (Lsmean), standard error (Stderr), standardized CPUE in number by **age 4** (Cpue4) and upper and lower 95% confidence limits (Ucpue4, Lcpue4) for the case base analysis of the North Atlantic for the years 1982-2019.

YR	LSMEAN	STDERR	Ucpue4	Cpue4	Lcpue4
1982	0.20084	0.21580	1.910	1.251	0.820
1983	-0.02228	0.17440	1.398	0.993	0.705
1984	0.00894	0.17288	1.437	1.024	0.730
1985	0.03123	0.17083	1.463	1.047	0.749
1986	-0.02844	0.16749	1.369	0.986	0.710
1987	0.07751	0.17151	1.535	1.097	0.784
1988	-0.08673	0.16657	1.289	0.930	0.671
1989	-0.18005	0.16689	1.175	0.847	0.611
1990	-0.15476	0.16689	1.205	0.869	0.626
1991	0.01127	0.16642	1.421	1.025	0.740
1992	0.04728	0.16616	1.472	1.063	0.768
1993	-0.16402	0.16628	1.192	0.861	0.621
1994	-0.31529	0.16577	1.024	0.740	0.534
1995	-0.17327	0.16487	1.178	0.852	0.617
1996	-0.40187	0.16502	0.937	0.678	0.491
1997	-0.56473	0.16592	0.798	0.576	0.416
1998	-0.66165	0.16597	0.724	0.523	0.378
1999	-0.51917	0.16735	0.838	0.603	0.435
2000	-0.18046	0.16771	1.176	0.847	0.610
2001	-0.39127	0.16737	0.952	0.686	0.494
2002	-0.37079	0.16720	0.971	0.700	0.504
2003	-0.18640	0.16849	1.171	0.842	0.605
2004	-0.43431	0.16936	0.916	0.657	0.471
2005	-0.67085	0.17054	0.725	0.519	0.371
2006	-0.70139	0.17224	0.705	0.503	0.359
2007	-0.91358	0.17627	0.575	0.407	0.288
2008	-0.59478	0.17744	0.794	0.560	0.396
2009	-0.45804	0.17822	0.911	0.643	0.453
2010	-0.65189	0.17386	0.744	0.529	0.376
2011	-0.43994	0.17405	0.920	0.654	0.465
2012	-0.44056	0.17700	0.925	0.654	0.462
2013	-0.53246	0.18041	0.850	0.597	0.419
2014	-0.19267	0.17810	1.188	0.838	0.591
2015	0.01704	0.17696	1.462	1.033	0.730
2016	-0.34411	0.17822	1.021	0.720	0.508
2017	-0.44447	0.18195	0.931	0.652	0.456
2018	-0.51337	0.18769	0.880	0.609	0.422
2019	-0.22753	0.19056	1.178	0.811	0.558

Table 3(e). Estimated parameters (Lsmean), standard error (Stderr), standardized CPUE in number by **age 5+** (Cpue5+) and upper and lower 95% confidence limits (Ucpue5+, Lcpue5+) for the case base analysis of the North Atlantic for the years 1982-2019.

YR	LSMEAN	STDERR	Ucpue5+	Cpue5+	Lcpue5+
1982	0.28187	0.20517	2.024	1.354	0.906
1983	0.02902	0.15536	1.413	1.042	0.768
1984	0.08271	0.15351	1.485	1.099	0.814
1985	-0.00125	0.15101	1.358	1.010	0.751
1986	-0.10040	0.14696	1.220	0.914	0.685
1987	-0.08892	0.15195	1.247	0.926	0.687
1988	-0.23525	0.14582	1.063	0.799	0.600
1989	-0.33402	0.14607	0.964	0.724	0.544
1990	-0.38454	0.14607	0.916	0.688	0.517
1991	-0.25669	0.14548	1.040	0.782	0.588
1992	-0.13099	0.14512	1.178	0.887	0.667
1993	-0.28829	0.14526	1.007	0.757	0.570
1994	-0.45538	0.14465	0.851	0.641	0.483
1995	-0.40072	0.14386	0.897	0.677	0.511
1996	-0.63155	0.14409	0.713	0.537	0.405
1997	-0.83095	0.14495	0.585	0.440	0.331
1998	-0.81509	0.14517	0.595	0.447	0.337
1999	-0.99399	0.14701	0.499	0.374	0.280
2000	-0.45619	0.14673	0.854	0.641	0.480
2001	-0.70092	0.14613	0.668	0.501	0.377
2002	-0.62859	0.14611	0.718	0.539	0.405
2003	-0.48495	0.14776	0.832	0.622	0.466
2004	-0.67138	0.14844	0.691	0.517	0.386
2005	-0.71127	0.14989	0.666	0.497	0.370
2006	-0.68543	0.15242	0.687	0.510	0.378
2007	-0.63926	0.15751	0.728	0.534	0.392
2008	-0.54641	0.15848	0.800	0.586	0.430
2009	-0.53201	0.16011	0.814	0.595	0.435
2010	-0.72498	0.15482	0.664	0.490	0.362
2011	-0.44065	0.15458	0.882	0.651	0.481
2012	-0.09580	0.15547	1.247	0.920	0.678
2013	-0.40657	0.16184	0.927	0.675	0.491
2014	-0.04129	0.15975	1.329	0.972	0.711
2015	0.11652	0.15810	1.551	1.138	0.835
2016	-0.00917	0.15862	1.369	1.003	0.735
2017	-0.01007	0.16525	1.387	1.004	0.726
2018	-0.30927	0.16958	1.038	0.745	0.534
2019	0.07219	0.17528	1.539	1.092	0.774

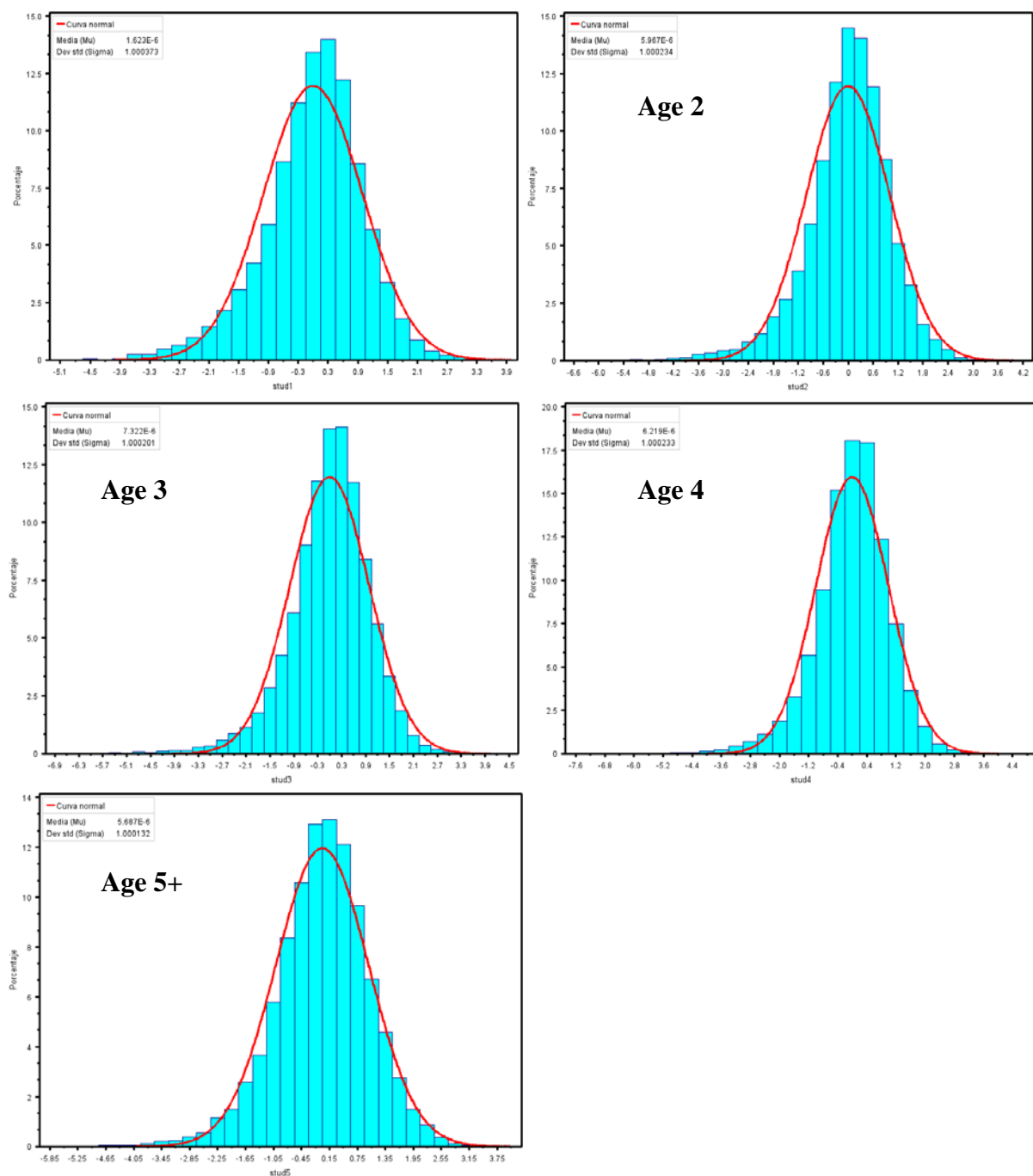


Figure 1. Normal fit and frequency distribution of the standardized residuals by age, years combined, obtained as diagnosis of the standardized CPUE in number of swordfish from the base case analyses of the North Atlantic stock for the period 1982-2019.

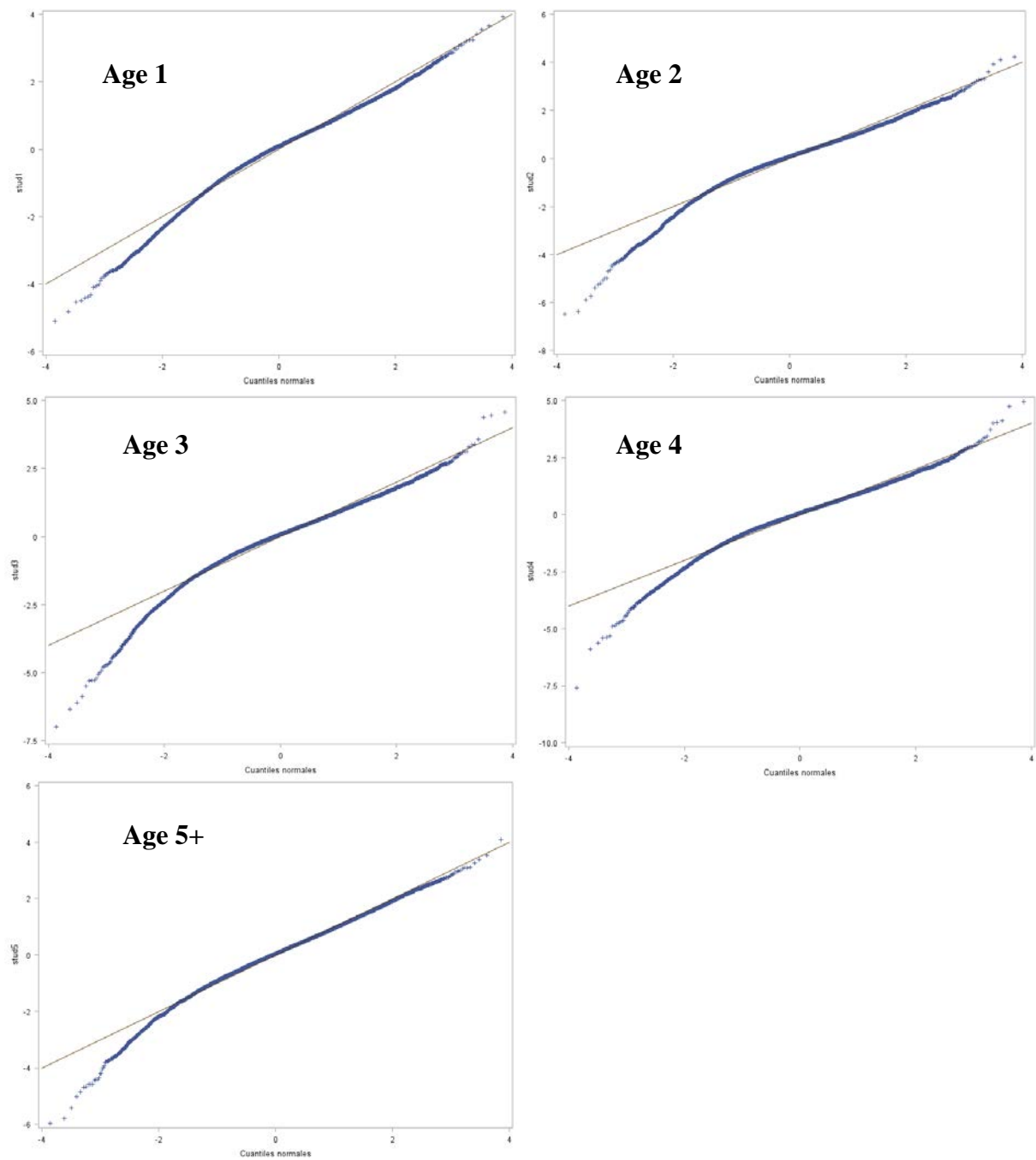


Figure 2. Normal probability qq-plot obtained for the GLM base case analyses for standardized CPUE in number of swordfish by age in the North Atlantic stock for the period 1982-2019.

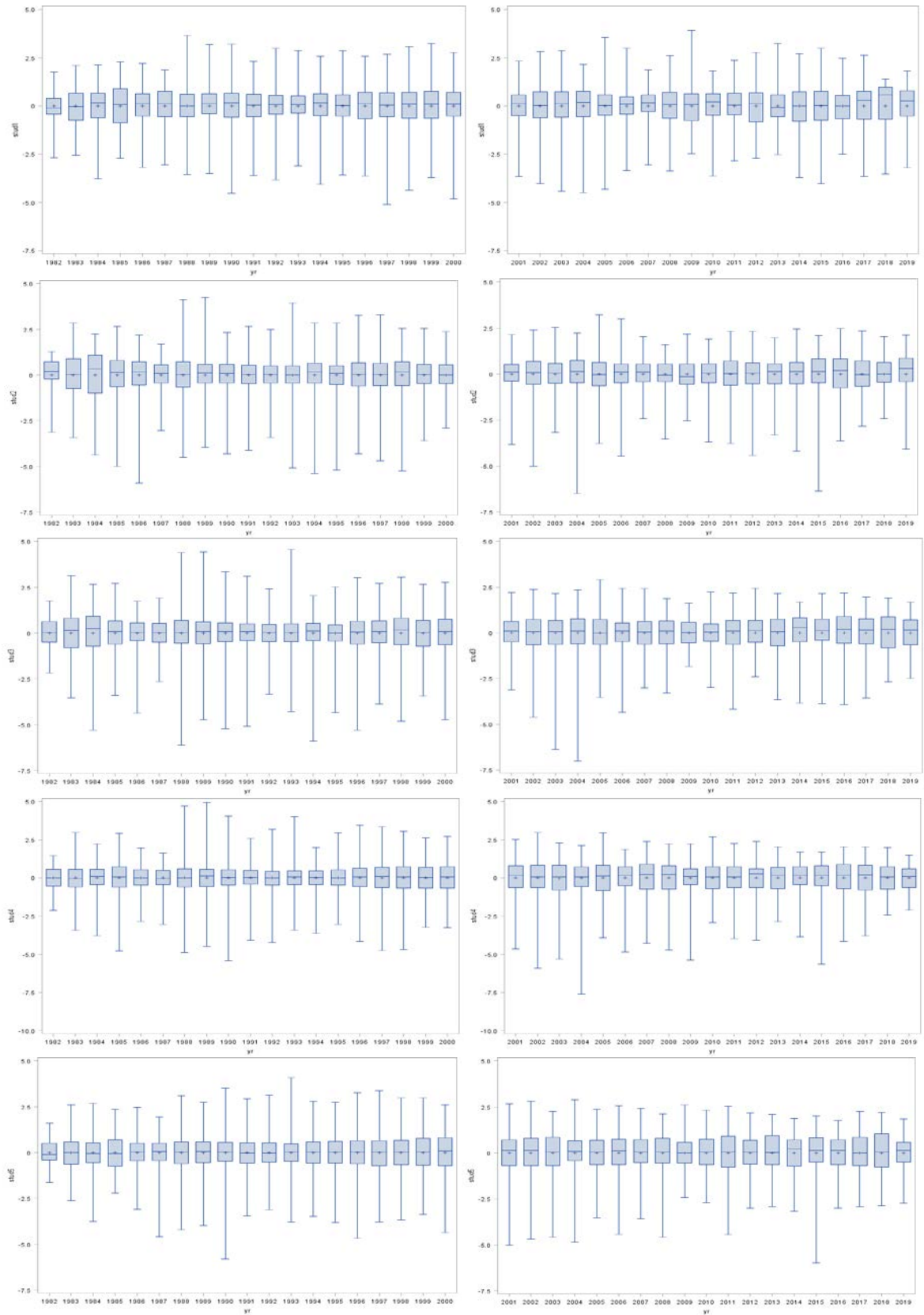


Figure 3. Variability box-plot of the standardized residuals by age and year obtained from GLM base case analyses of the standardized CPUE in number of swordfish by age for the North Atlantic stock during the periods 1982-2000 (left panels) and 2001-2019 (right panels). Respective ages from Age 1 (top panels) to Age 5+ (bottom panels).

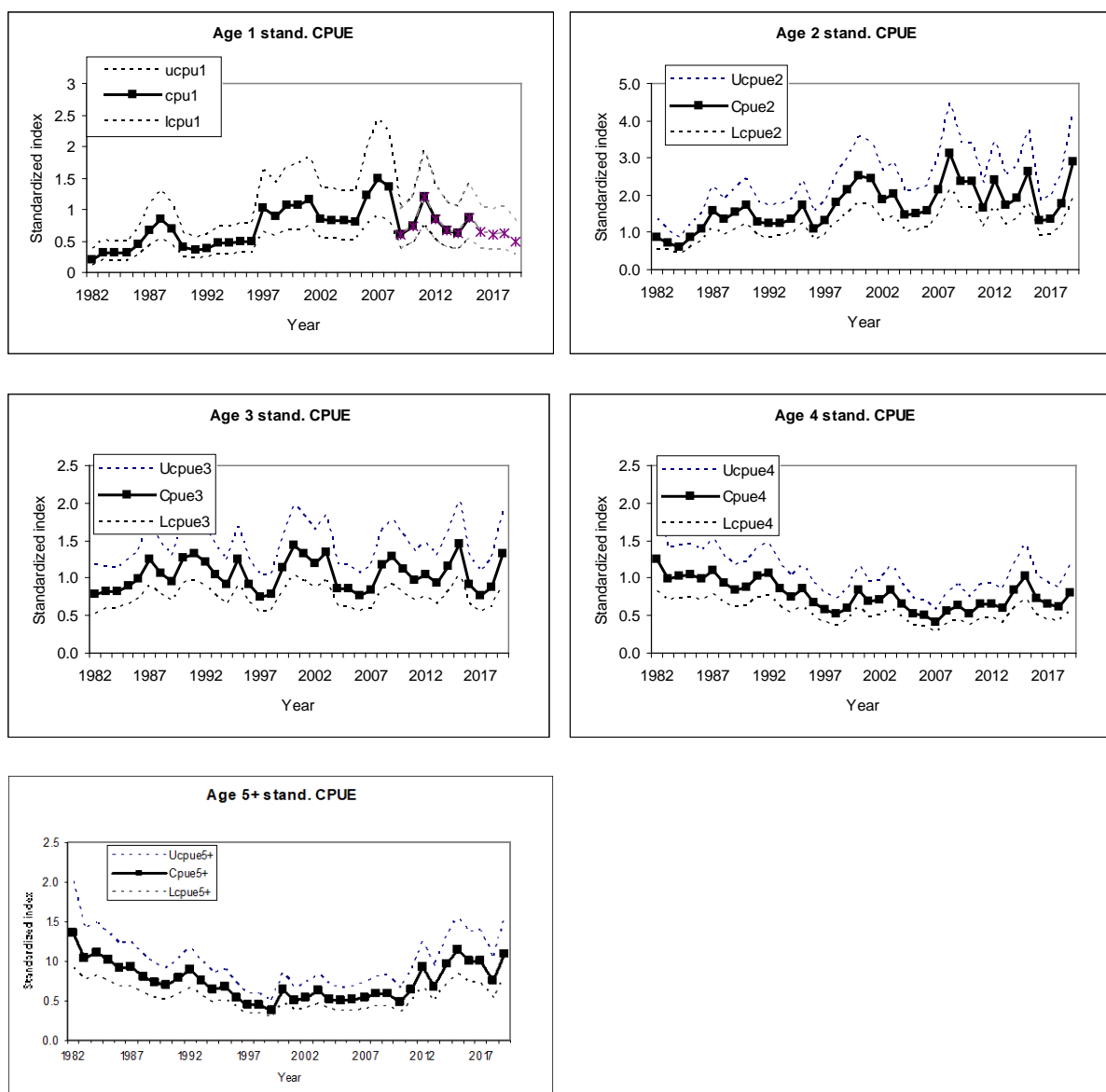


Figure 4. Annual change of the standardized catch rates in number of fish per thousand hooks for ages (1-5+) and 95% confidence intervals obtained in the North Atlantic, for the period 1982-2019.

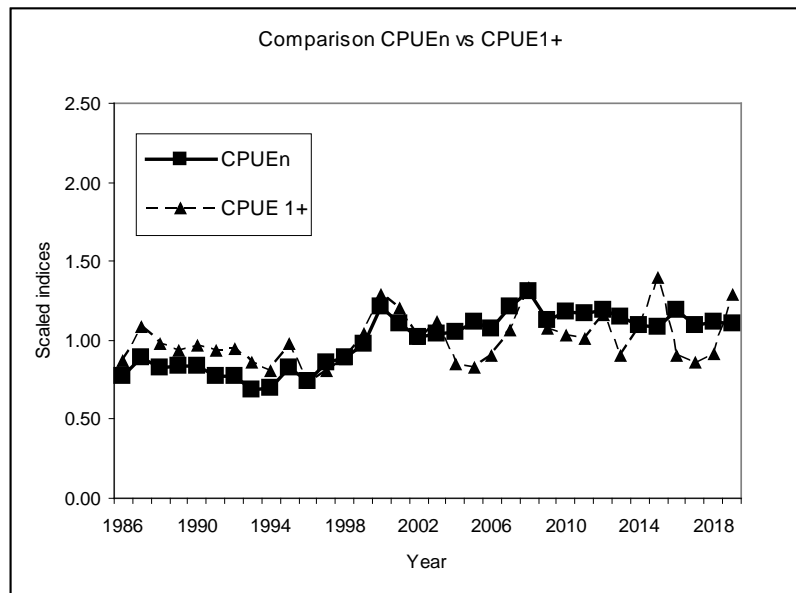


Figure 5. Comparison between the scaled mean values of the standardized CPUE in number of fish aggregated (see Ramos-Cardelle *et al.* 2021-in press) and the scaled base case standardized CPUE in number of fish by age (additive ages: CPUE 1+) obtained in the present study.